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Contact e-mail:
alexandre.poulin@epfl.ch

Pad printing 1-10 μm thick elastomer membranes for DEAs

Alexandre Poulin, Samuel Rosset, and Herbert Shea

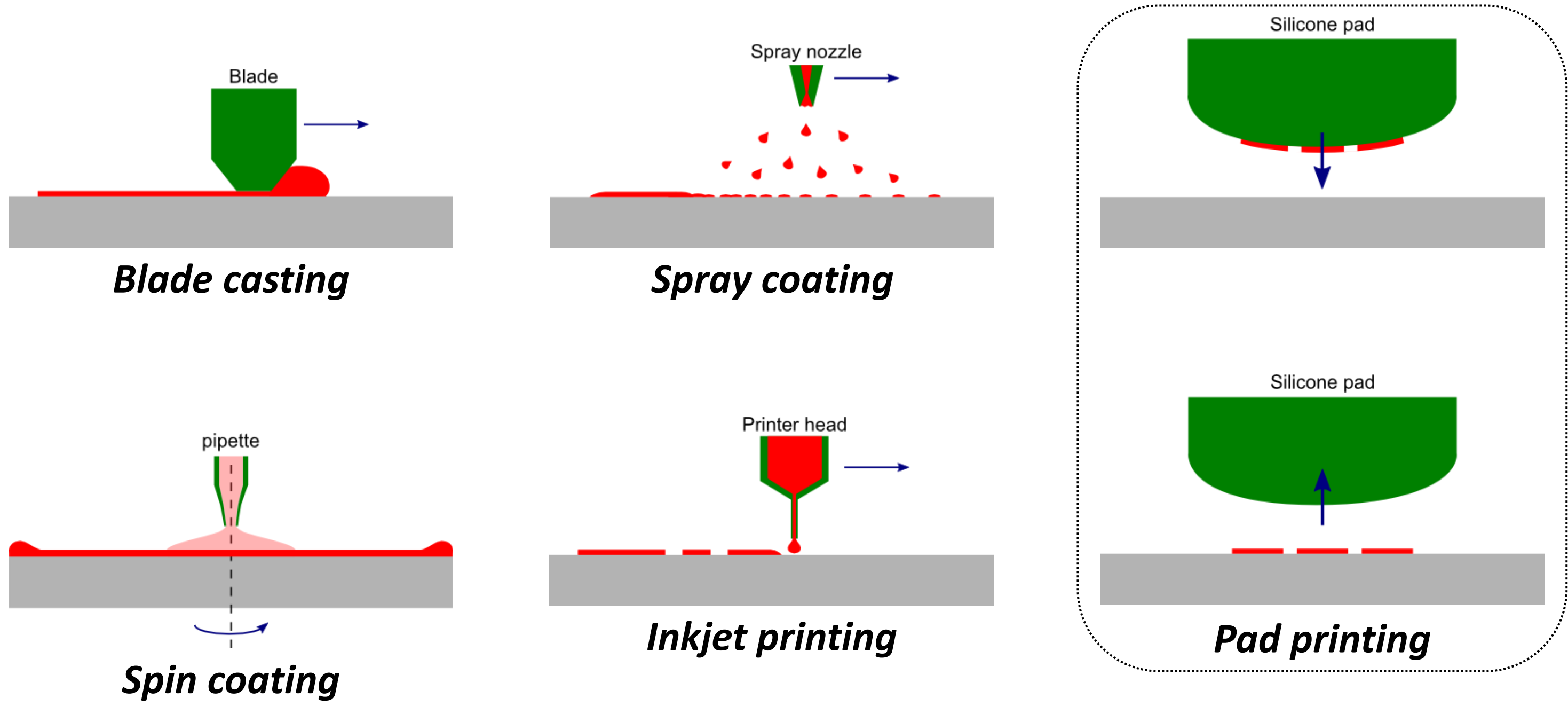
Microsystems for Space Technologies Laboratory, Ecole Polytechnique Fédérale de Lausanne, Neuchâtel, Switzerland

Abstract

We present a technique for stamping patterned silicone elastomer membranes with thicknesses ranging from 1 to 10 μm . Silicone elastomers are becoming the material of choice for dielectric elastomer transducers. The variety of readily available materials, their versatility in terms of film thicknesses and their excellent mechanical properties have made them a very appealing alternative to the widely used acrylic elastomer VHB from 3M. Silicone films are typically blade casted or spin coated, two complementary techniques allowing for large area ($> 10\text{ cm} \times 10\text{ cm}$) and ultra-thin ($< 1\text{ }\mu\text{m}$) membranes respectively.

We present a stamping method for membranes up to $5\text{ cm} \times 5\text{ cm}$ in area and with thicknesses ranging from 1 to 10 μm . Unlike blade casting and spin coating this technique enables direct patterning of the membrane, thus providing great design flexibility. Combined with the ability to pattern stretchable electrodes using the same method [1], functional structures such as dielectric elastomer actuators (DEAs) with high level of integration (vertical integration) can be fabricated. As a proof of concept we characterized a stamped DEA, as well as a stamped vertical electrical connection for layers interconnection.

I – Silicone elastomer films production methods

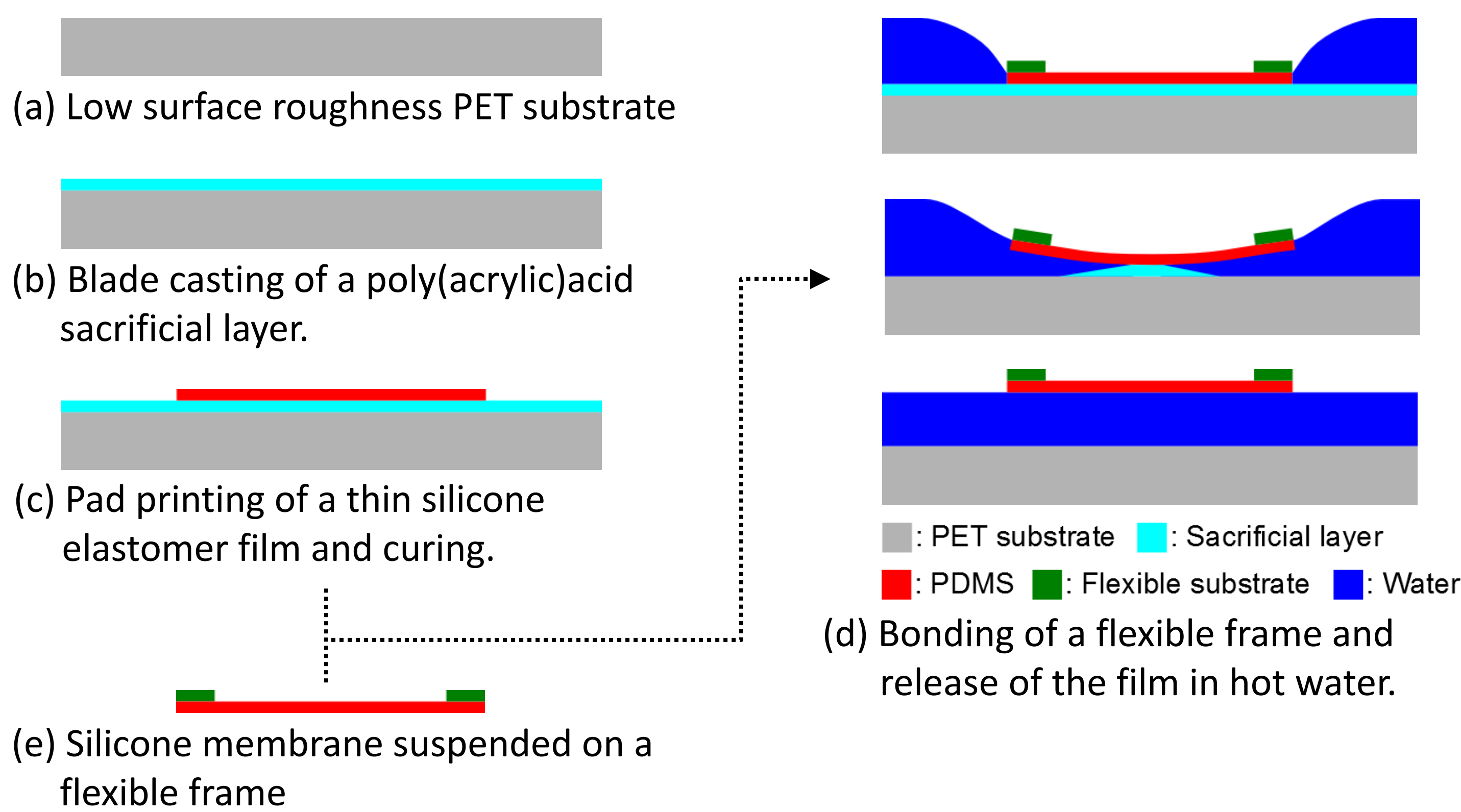


Membrane:	Blade casting	Spin coating	Spray coating	Inkjet printing
Thickness	Medium-high	Low-high	Medium-high	Low
Uniformity	Good	Medium	Medium	Medium
Area	Large	Medium	Large	Medium
Geometry	Rectangular	Circular	Substrate	Arbitrary
Complexity	Low	Medium	Medium	High

This work

Pad printing
Low
Medium
Medium
Arbitrary
Low

II – Pad printed silicone elastomer thin membranes



Silicone elastomer membranes of 1 to 10 μm in thicknesses were printed by simply adjusting the number of prints and the pressure exerted on the substrate by the pad.

The viscosity of the printed solution, its self-leveling properties and its pot life at room temperature are important parameters that influence the membrane quality.

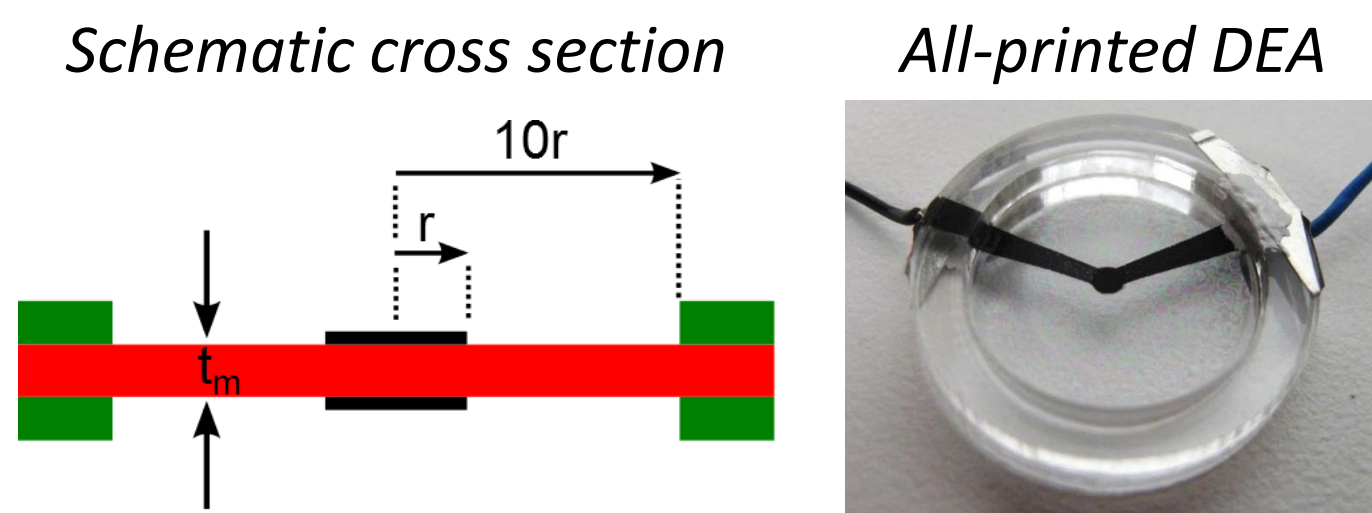
Acknowledgments

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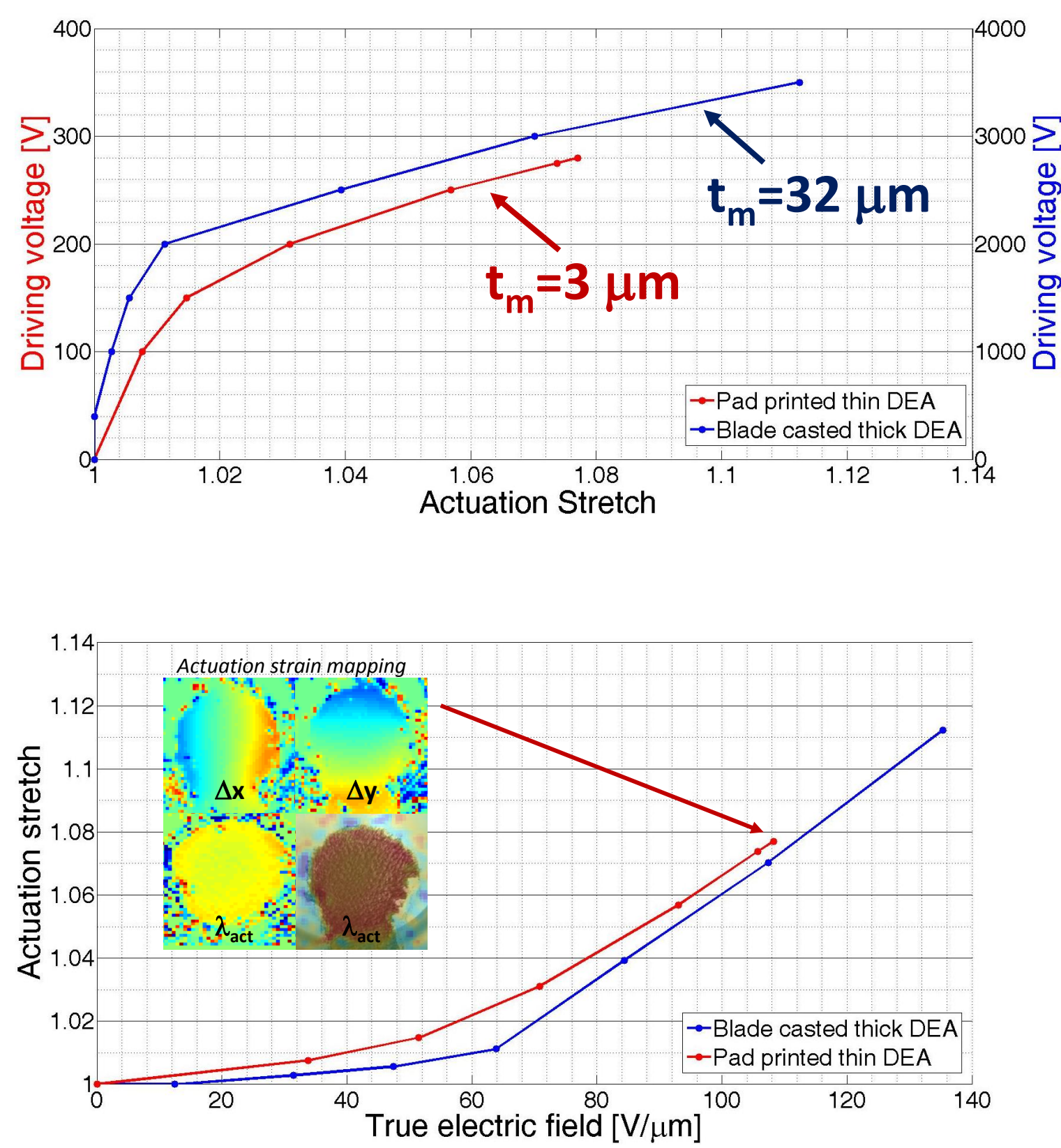
III – Low voltage actuation in all-printed DEA

The same printing technique can also be used to pattern stretchable electrodes on the membrane and manufacture DEAs.

Using a 3 μm thick membrane we achieved 8% stretch (biaxial) at 280 V, a voltage ten times lower than the one required with our standard 30 μm thick membranes.

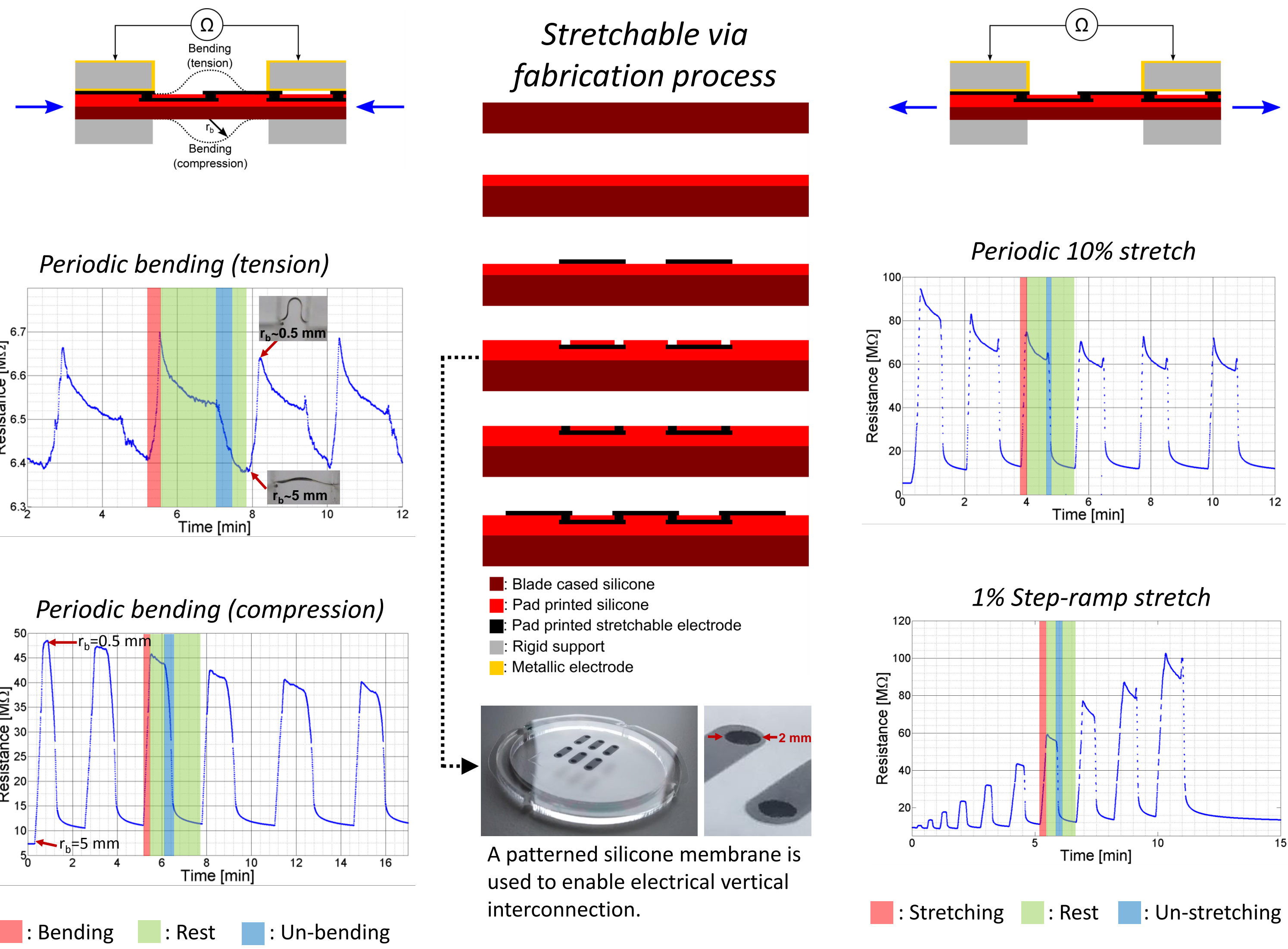


Silicone elastomer:.....Sylgard 184
Pre-stretch:1.2
Thicknesses after pre-stretch:
Blade casted DEA..... $t_m=32\text{ }\mu\text{m}$
Pad printed DEA..... $t_m=3\text{ }\mu\text{m}$



IV – Stretchable vertical electrical interconnection (via)

Using a multi-step process, stamping silicone and electrodes, we fabricated stretchable vias to demonstrate an application of membrane patterning. Lines of four vertical via were fabricated and characterized under pure shear stress and bending. The via ($\varnothing=2\text{ mm}$) remained conductive at bending radius lower than 0.5 mm and at stretch greater than 10%.



Conclusion

We demonstrated a new silicone elastomer films production method for DEAs which presents interesting advantages:

- Ability to manufacture thin (1-10 μm) silicone membranes.
- Ability to directly pattern the silicone membrane with 100 μm feature size.
- Same technique can be used to pattern elastomer-based stretchable electrodes.
- Low system complexity

An all-printed silicone-based DEA working at a voltage 10 times lower than its equivalent blade casted actuator was presented.

A stretchable via was fabricated to demonstrate the advantage of direct membrane patterning. The via remained conductive at bending radius below 0.5 mm and under tensile stretch higher than 10%.

References

1. S. Rosset and H. Shea. Towards fast, reliable, and manufacturable DEAs: miniaturized motor and Rupert the rolling robot. Electroactive Polymer Actuators and Devices (EAPAD), San Diego, 2015.